

# **THERAPEUTIC AND PROPHYLACTIC TREATMENT OF AGING AND DISORDERS OF AGING IN HUMANS**

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## INTRODUCTION

## Field of the Invention

This invention deals with therapeutic and prophylactic treatment of age-related problems with humans. More specifically, a new use for existing medicaments that will counteract the aging process on a cellular level -- particularly in the brain -- is disclosed.

## Background

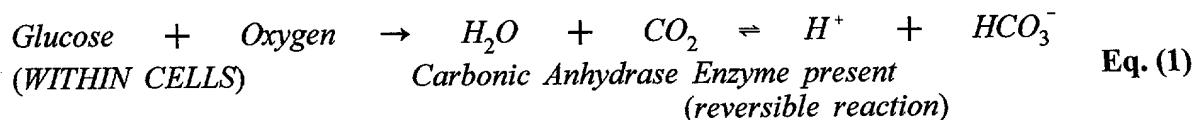
Normal aging in humans is recognized as producing some or all of the following typical physiological results:

1. Brain weight is reduced by 15%
2. Blood flow to the brain is reduced by 20%
3. Body water content is reduced by 18%
4. Body weight is reduced by 12%
5. Nerve conduction velocity is reduced by 10%
6. Number of nerve fibers in nerves are reduced by 37%
7. Decreased amounts of enzymes and coenzymes
8. Decreased amounts of neurotransmitters
9. Depletion of oxidative, phosphohorelative enzymes
10. Apoptosis-- chronic neuronal atrophy

In describing their work in an article entitled "Studies on Age-Dependent Ozonide Changes in Human Cerebral Cortex," (by Reichlmeier K., Ermini M., and Schlecht H. P.--*Aktuelle Gerontol* 1978 Aug., 8(8):44-8), the authors report that they investigated the activity of

1 various enzymes of human brains obtained at autopsy and covering an age range from 19 to 91  
2 years. Protein kinase, which mediates the information carried by the second messenger,  
3 cyclic AMP (3',5'-cyclic adenosine monophosphate), does not show age-related changes of basal  
4 activity. Cyclic AMP-dependent activation of protein kinase remains nearly constant up to 60  
5 years of life, but it undergoes a distinct and progressive decline between 60 and 90 years. In the  
6 *corpus striatum*, no age related changes of cyclic AMP-dependent protein kinase activity were  
7 observed. The activity of carbonic anhydrase exhibits, in both human cortex and *corpus striatum*,  
8 an age-dependent decrease that also begins after the sixth decade of life. These neurochemical  
9 changes may well be related to morphological and physiological changes occurring in the aging  
10 brain. They begin after the 60th year of life.

The following represents an essential chemical reaction that takes place in human tissue:



Glucose is irreversibly oxidized within the cells to produce water and carbon dioxide. In the presence of a catalyst, especially a carbonic anhydrase enzyme (of which several forms exist, of which the form present depends upon the type of tissue cells present), the water and carbon dioxide reversibly produce a hydrogen ion and a bicarbonate ion.

16            Carbonic anhydrase is a zinc-containing enzyme that catalyzes the reversible CO<sub>2</sub>  
17    hydration reaction illustrated in Eq. 1. The mitochondria of cells of different tissues and organs  
18    produces different specific carbonic anhydrase enzymes that maintain the equilibrium of the  
19    above equation in all spaces -- cellular, interstitial, and vascular -- as illustrated in Fig. 1. At least  
20    seven carbonic anhydrase variants, called "isozymes" have been identified. The literature may  
21    refer to these as "carbonic anhydrases I through VII" or "CAS I-VII". We here refer to this  
22    selectivity as "cell-specific" and the particular carbonic anhydrase isozyme present as being a  
23    "cell-specific carbonic anhydrase enzyme."

Hydrogen ion produced by carbonic anhydrase enzymes is acted upon by cytochrome

1 system, which is then utilized as the energy source of the ion pump that maintains the integrity of  
2 the cell membrane comprising and enclosing each cell. It is also thought to be a source of the  
3 brain's electric current. This process is schematically illustrated in Fig. 1, presented here with no  
4 further discussion.

5 Disruption of the process that includes Eq. 1 causes depolarization of the cell wall  
6 membrane, hence sodium (Na), water (H<sub>2</sub>O), and other chemicals can enter the cell in uncon-  
7 trolled amounts and potassium (K) can exit uncontrollably, leading to the death and destruction  
8 of the involved cells; cellular edema follows. As this edema progresses, the cell dies. Along with  
9 the progressive and gradual death of cells, gliosis follows-- hence aging in the brain occurs.

10 In aging, there has been observed a progressive decrease in levels of enzymes of which  
11 carbonic anhydrase enzyme is one. Authors W. Meier-Ruge, P. Iwangoff, K. Reichlmeier, and P.  
12 Sandoz, in "Neurochemical findings in the Aging Brain (Adv. Biochem Psychopharmacology  
13 1980;23:323-38) include carbonic anhydrase in their studies of normal aging on enzymes in the  
14 human brain cortex and putamen. Their study shows carbonic anhydrase, which they cite as  
15 being important to the regulation of the pO<sub>2</sub>/pCO<sub>2</sub> ratio in the brain tissue, demonstrates a  
16 significant decline with increasing age. Thus, pCO<sub>2</sub>-dependent regulation of tissue pH, ionic  
17 transport processes, and cerebral blood flow regulation have the tendency to become more and  
18 more unstable, they observe.

19 Authors E. Cabisco and R. L. Levine, in "Carbonic anhydrase III. Oxidative modification  
20 *in vivo* and loss of phosphatase activity during aging" (J. Biol. Chem. 1995 Jun 16;270(24):  
21 14742-7), describe their utilizing an immunochemical method for detection of  
22 oxidatively-modified proteins, through which method they identified a protein in rat liver that  
23 was highly oxidized. It was purified to homogeneity and identified as carbonic anhydrase  
24 isozyme III. Its characteristics match those previously described for protein that was lost during  
25 aging of the rat, senescence marker protein-1. In their experiments, carbonic anhydrase III was  
26 purified from rats aged 2, 10, and 18 months and the proteins were characterized. All three  
27 preparations were highly oxidative modified, as assessed by their carbonyl content. The enzyme  
28 (carbonic anhydrase III) has three known catalytic activities, and the specific activities for carbon  
29 dioxide hydration and for ester hydrolysis decreased during aging by approximately 30%.

1 However, the third activity, that of a phosphatase, was virtually lost during aging. While the  
2 physiologic role of carbonic anhydrase III is unknown, these authors suggest that it functions as  
3 an oxidizing environment, which leads to its own oxidative modification.

4

5 PRIOR ART

6 Carbonic anhydrase enzyme has been used to augment the extracellular pH buffering in  
7 the cerebral cortex of rats (*Journal of Neurophysiology* 1995 Oct.'74(4):1806-9). It is known that  
8 the blood-brain barrier in animals is incomplete compared to that of humans where the  
9 blood-brain barrier is complete and a formidable barrier to chemical transport. Substances that  
10 prove efficacious in affecting the brain chemistry of animals are not necessarily efficacious in the  
11 brains of human beings because they cannot pass through the more complete blood-brain barrier  
12 in humans. Carbonic anhydrase enzymes appear to traverse the blood-brain barrier in humans.  
13 Although some researchers equivocate on this concept, most of the medical community accepts  
14 the idea that carbonic anhydreas enzymes traverse the blood-brain barrier in humans as fact,  
15 especially regarding the carbonic anhydrase enzyme referred to as CA-II.

16 As far as can be determined from the literature, cell-specific carbonic anhydrase enzymes  
17 have never been used to restore to a higher level the carbonic anhydrase enzymes that are lacking  
18 due to decreased levels due to normal aging. At least some of the carbonic anhydrase isozymes  
19 have been extracted from animal tissue, isolated, and studied for molecular structure. This shows  
20 that the enzymes can be isolated and made available for administration to a patient for  
21 therapeutic or prophylactic treatment.

22 In U.S. Patent number 5,972,684, Bandman et al. tell us:

23 "Eight enzymatic and evolutionarily related forms of carbonic anhydrase are  
24 currently known to exist in humans: three cytosolic isozymes (CAI, CAII, and CAIII,  
25 two membrane-bound forms (CAIV and CAVII), a mitochondrial form (CAV), a  
26 secreted salivary form (CAVI) and a yet uncharacterized isozyme. Isoforms show a  
27 characteristic motif. (See, e.g., <http://expasy.hcuge.ch>). Though the isoenzymes CAI,  
28 CAII, and bovine CAIII have similar secondary structure and polypeptide-chain fold,  
29 CAI has 6 tryptophans, CAII has 7 and CAIII has 8 (Boren, K. et al. (1996) Protein

1 Sci. 5(12):2479-2484). CAII is the predominant CA isoenzyme in the brain of  
2 mammals.”

3 “Inhibition and activation of CA provide information about CA structure and  
4 activity. Vasodilating prostaglandins E1, E2 and I2 inhibit CA in vitro and in vivo  
5 and may inhibit the involvement of CA in gastric acid secretion. Nonsteroidal anti-  
6 inflammattory drugs which reduce the activity of cyclooxygenase and prostaglandin  
7 production have also been observed to activate CAI and CAII in a dose-dependent  
8 noncompetitive manner. The pre-prostaglandin cyclooxygenase appears to maintain  
9 an inverse relationship with CA, probably mediated by the pH variations associated  
10 with carbonic anhydrase activity (Puscas, I. (1996) J. Pharmacol. Exp. Ther.  
11 277(3):1464-1466). Both prostaglandins E2 and I2 inhibit gastric acid output.  
12 Prostaglandin E2 inhibits egress of norepinephrine from sympathetic nerve  
13 terminals.”

14 The Bandman et al. patent teaches another carbonic anhydrase, CA-VIII, the subject of  
15 their patent. The present patent does not deal with nor address CA-VIII.

16 Patients having a carbonic anhydrase VI (CA-VI) deficiency have been treated with  
17 orally-administered zinc in an effort to stimulate the synthesis/secretion of CA-VI and the  
18 successful results were reported in the American Journal of Medical Science (Efficacy of  
19 exogenous oral zinc in treatment of patients with carbonic anhydrase VI deficiency, by Henkin,  
20 R.I., Martin, B.M., and Agarwal, R. P. -- *Am J Med Sci* 1999 Dec;318(6):392-405). Thus, it is  
21 shown that the synthesis/secretion of carbonic anhydrase can, indeed, be stimulated by  
22 compounds administered orally.

#### 23 24 BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig. 1 illustrates the pathophysiology of neurodegenerative disorders.

#### 26 27 DESCRIPTION OF THE BEST MODE

28 Referring to Fig. 1, we observe two parallel paths of cell destruction that can be directly  
29 linked to deficiencies of cell-specific carbonic anhydrase enzymes, whether the decreased level

1 of CA is a primary deficiency or a secondary deficiency, as described therein. One path relates to  
2 the breakdown of the chemical reaction shown in Eq. 1 and the other relates to the release of  
3 caspase, leading to apoptosis. The result of both paths is dead cells and dying cells, which  
4 include brain cells and other neural cells. Here we show that at least one cause of the destruction  
5 of brain cells and other neurons is traceable to decreased levels of cell-specific carbonic  
6 anhydrase enzymes.

7 Heretofore, researchers had identified only one of these parallel paths, the one involving  
8 caspase. Specifically, it has been reported in the Journal of Infectious Diseases, 2000  
9 September;182 Suppl 1:S85-92, by F. Chai, et al. that the mechanism by which zinc deficiency  
10 (equivalent to deficiency in zinc-carrying carbonic anhydrase enzyme) induces epithelial cell  
11 death involves the activation of caspase-3 as indicated on the right half of Fig. 1. The suggestion  
12 is made from this research that zinc (i.e., CA) may suppress a step just before the activation of  
13 the caspase and a zinc (i.e., CA) deficiency results in a failure to suppress that step.

14 The path illustrated on the left half of Fig. 1 is newly presented in the instant invention.  
15 The decreased levels of CA (i.e., zinc-carrying enzyme) upset the rate of the reversible portion of  
16 the reaction indicated in Eq. 1, above, decreasing the formation of hydrogen ion that is the fuel  
17 for the ion pump that maintains the cell wall membrane, leading to depolarization and allowing  
18 neurotoxic substances to enter the cell, causing edema and cell death.

19 Whereas in aging, there has been observed a progressive decrease in levels of enzymes of  
20 which carbonic anhydrase enzyme is one, I believe that replenishing the carbonic anhydrase  
21 enzymes that catalyze the reversible reaction portion of Equation 1 will at least slow the  
22 progressive and gradual death of cells, including cells in the brain, which brain cell reduction is a  
23 major contributor to various brain disorders involving dementia such as Alzheimer's disease, and  
24 neurodegenerative diseases.

25 Cell-specific carbonic anhydrase enzymes have never been used to restore to a higher  
26 level the carbonic anhydrase enzymes that are lacking due to decreased levels due to normal  
27 aging, whether the replenishing enzymes are naturally produced and harvested or synthetically  
28 produced, nor has anyone used for this purpose any carbonic anhydrase stimulators to stimulate a  
29 patient's production of carbonic anhydrase enzymes.

1 I have come to the realization that administering supplemental cell-specific carbonic  
2 anhydrase enzymes or administering cell-specific carbonic anhydrase enzyme stimulators, the  
3 effects of aging, especially in the central nervous system, by raising the level of cell-specific  
4 carbonic anhydrase enzymes present. In using the term "stimulators" I mean to include materials  
5 for stimulating the production of cell-specific carbonic anhydrase enzymes. Another method for  
6 raising the level of the required enzymes is to directly administer the enzymes themselves. These  
7 enzymes can be naturally-produced enzymes or synthetically-produced enzymes. Means and  
8 techniques are available in the medical literature for extracting naturally-produced enzymes.

9 This treatment can be administered to patients exhibiting signs of Alzheimer's disease or  
10 showing other forms of dementia or neurodegenerative diseases. It is also feasible to administer  
11 this treatment as a prophylactic or preventative to an aging patient to prevent or at least delay the  
12 onset of such dementia, from whatever cause.

13 Thus, I disclose here a method for the treatment and prophylaxis of conditions of aging  
14 associated with a decreased presence of cell-specific carbonic anhydrase enzymes in the brain,  
15 such as conditions associated with chronic neurodegenerative conditions including dementia such  
16 as Alzheimer's disease, which method comprises the administration over an extended period of  
17 time in the range of six months to five years, of a pharmaceutically effective, non-toxic amount  
18 of a compound that increases the presence of a cell-specific carbonic anhydrase enzymes in the  
19 brain. The carbonic anhydrase enzyme found most abundantly in the brain is referred to as CA-II;  
20 the method may be applied to other carbonic anhydrase enzymes as well as to CA-II.

21 The compound used could be the cell-specific enzyme that is believed to be evidencing a  
22 decreased presence as measured in blood tests or in cell cultures of brain cells from biopsied  
23 tissues or from cerebro-spinal fluid. Alternatively, the compound used could be synthetically  
24 produced cell-specific carbonic anhydrase enzyme. As another alternative, the compound used  
25 could be naturally-produced cell-specific carbonic anhydrase enzyme. Yet another alternative  
26 allows that the compound used is a compound that, when administered to a human patient will  
27 promote the natural production of the cell-specific enzyme that is evidencing a decreased  
28 presence as measured in blood tests or in cell cultures of brain cells from biopsied tissues or from  
29 cerebro-spinal fluid. The compound itself need not be one that passes the blood-brain barrier; the

1 cell-specific enzyme need not be produced within the brain for it is known to pass the blood-  
2 brain barrier so the promoting of the natural production of the cell-specific enzyme can take  
3 place elsewhere in the body.

4 Examples of compounds that are known to promote the natural production of the required  
5 cell-specific enzyme comprise: zinc; sex hormones, androgen and estrogen; certain non-steroidal  
6 anti-inflammatory drugs, including indomethacin; 1,25-dihydroxyvitamin D3; phorbol myristate  
7 acetate; cysteamine; and certain sulfonlamido derivatives of histamine. For instance, the sex  
8 hormones androgen and estrogen are known to increase the production of carbonic anhydrase III.  
9 Vitamin D3 increases the production of carbonic anhydrase II.

10 Administering the compound may be done by injection or ingestion. The injection  
11 method used may be intramuscular or intravenous, dissolved in a sterile saline solution, glucose  
12 solution, or other commonly-administered parenteral solution. The best method of administering  
13 the compound will be learned with modest experimentation. The individual patient's response to  
14 the compound will be learned through testing for the cell-specific enzyme in blood samples taken  
15 before and after administering the medication and by enzyme levels measured from cell cultures  
16 of brain cells from biopsied tissues or found in cerebro-spinal fluid. The goal is to increase the  
17 level of the cell-specific enzyme in the brain from its reduced level to a more normal level.  
18 Insofar as the enzyme level in the blood is a reflection of the enzyme level in the brain, the blood  
19 tests may be a sufficient indicator. In addition, and other means of measuring enzyme levels that  
20 are known to the practitioner may be employed.

21 Pharmaceutical compositions suitable for use in the invention include compositions  
22 wherein the active ingredients are contained in an effective amount to achieve the intended  
23 purpose. The determination of an effective dose is well within the capability of those skilled in  
24 the art.

25 A therapeutically effective dose refers to that amount of active ingredient that ameliorates  
26 the symptoms or condition, the condition being caused by or reflected in reduced concentration  
27 of carbonic anhydrase. Therapeutic efficacy and toxicity may be determined by standard  
28 procedures from blood testing, from biopsied tissues, and by other means known to the  
29 practitioner, for comparison with the normal values. The dosage is preferably within a range of

1 circulating concentrations that are efficacious with little or no toxicity. The dosage varies within  
2 this range depending upon the dosage form employed, sensitivity of the patient, and the route of  
3 administration.

4 The exact dosage will be determined by the practitioner, in light of factors related to the  
5 subject that requires treatment. Dosage and administration are adjusted to provide sufficient  
6 levels of the active moiety or to maintain the desired effect, which is a near-normal level of the  
7 cell-specific enzyme. Factors which may be taken into account include the severity of the enzyme  
8 reduction extant in the subject, general health of the subject, age, weight, and gender of the  
9 subject, diet, time and frequency of administration, drug combination(s), reaction sensitivities,  
10 and tolerance/response to therapy. Long-acting pharmaceutical compositions may be  
11 administered every 3 to 4 days, every week, or once every two weeks depending on half-life and  
12 clearance rate of the particular formulation.

13 Normal dosage amounts may vary from 0.1 to 100,000 micrograms, up to a total dose of  
14 about 1 gram, depending upon the route of administration. Guidance as to particular dosages and  
15 methods of delivery is provided in the literature and generally available to practitioners in the art.  
16 Those skilled in the art will employ different formulations to achieve the desired results.      ###